Reprinted from *1995 Columbia Basin Agricultural Research Annual Report. Spec. Rpt. 946,* pp. 67-72 1995
Oregon State University in cooperation with USDA-Agricultural Research Service, Pendleton, OR

DAMAGE TO WINTER WHEAT FROM DRYLAND ROOT ROT

Richard Smiley and Lisa-Marie Patterson

INTRODUCTION

Winter wheat root, crown, and foot (culm) rots caused by *Fusarium culmorum*, *F. graminearum*, *F. avenaceum*, *Bipolaris sorokiniana,* and others, are known as dryland root rot, Fusarium root rot, common root rot, or crown rot. Dryland root rot is the name used in this paper. Dryland root rot appears to cause at least some damage to crops during most years. Damage is highly variable within as well as among fields. Effects of crop management systems on the incidence and severity of dryland root rot are not well defined.

There are no estimates of economic damage caused by dryland root rot in the Pacific Northwest. Damage estimates provide several important types of information. Effects on grain yield and test weight provide information on farm profitability. Effects on grain protein content provide an insight into the milling and baking quality of the flour. Effects on straw yield are important to Conservation Compliance Provisions of the 1985 Food Security Act (Farm Bill). Damage estimates are needed to determine whether research on disease control is justified.

Objectives of this study were to determine effects of dryland root rot on grain yield, straw yield, test weight, kernel weight, and protein of winter wheat.

METHODS

Thirteen fields of mature winter wheat were selected for sampling during 1994. Seven fields were in Gilliam and Sherman Counties of Oregon, and six were in Benton and Walla Walla Counties of Washington. Varieties of winter wheat in each field were not determined until after sampling had been completed. This was done to avoid biasing results through inadvertant selection of fields with varieties or classes of wheat considered highly susceptible to dryland root rot.

All plants in a 10-foot row section were collected (dug up) from two randomly selected areas in each of 13 fields (26 samples). Numbers of plants with and without symptoms of dryland root rot were recorded. Tillers were then separated and leaf sheaths removed to expose culms. Tillers in each sample were separated into root rot classes representing the extent of culm browning attributed to dryland root rot. Root rot severity classes were D_0 (none), D_1 (browning up to the first node), D_2 (second node), D_3 (third node), and D_4 (4th node or above). Measurements of plant characteristics within each root rot classification included numbers of tillers, tillers without heads, percentage of headed tillers, straw weight, tiller height, grain weight, grain protein (calculated by multiplying percent N in grain by 5.7), and kernel weight.

Estimates of crop damage caused by dryland root rot were based on regression analyses of disease severity characteristics on individual tillers. Characteristics for calculating yield loss included five disease severity classes (described above), number of headed tillers (T) in each severity class, and grain weight/tiller for tillers in each severity class (G_{Dx}), where the "x" in "D_x" represents disease severity class numbers 0, 1, 2, 3, or 4. The measured yield (MY) for each bundle was calculated by adding grain weights obtained from heads in each severity class. Potential yield (PY) was calculated by

Table 1. Provisional dryland root rot ratings for winter wheat varieties; averaged data for incidence of whiteheads† in five wheat breeding nurseries in northeast Oregon from 1991 to 1994.

Category	White-heads/ft	Variety
Tolerant	<3	Basin, Dusty, Gene, Hyak, Madsen, Rohde, Rulo, Yamhill
Mod. Tolerant	2-5	Cashup, Eltan, Hill 81, Kmor, Lewjain, Rely, Tres
Highly Variable or Susceptible	2-22	Andrews, Batum, Buchanan, Daws, Durheim's Pride, Hoff, MacVicar, Malcolm, NuGaines, Rod, Stephens, Ute, Wanser, W301

† Whitehead counts were averaged for breeding nurseries at Arlington (1991), Lexington (1991), Moro (1993 & 1994), and Pendleton (1994).

adding numbers of headed tillers in each severity class and multiplying the sum by the grain weight/tiller, as obtained from healthy tillers in class D_0. The percentage yield loss (%YL) was then calculated by subtracting MY from PY, multiplying by 100, and dividing by PY. Equations for these calculations were as follows:

$$MY = G_{D0}+G_{D1}+G_{D2}+G_{D3}+G_{D4}$$

$$PY = (T_{D0}+T_{D1}+T_{D2}+T_{D3}+T_{D4})\ G_{D0}$$

$$\%\ YL = [(PY-MY)\ 100]\ /\ PY$$

For example, if the MY was equivalent to 42 bu/acre and the PY was estimated at 45 bu/acre, the percent yield loss from dryland root rot would be 6.7 percent.

RESULTS AND DISCUSSION

Six winter wheat varieties were represented in the 13-field sample from four counties. Varieties and county locations were; Gene (1 field in Benton), Lewjain (1 in Benton), Madsen (2 in Sherman; 1 in Walla Walla), Malcolm (1 in Gilliam), Stephens (3 in Gilliam, 1 in Sherman, 1 in Walla Walla), and Weston (2 in Benton).

Percentages of plants with dryland root rot ranged from 24 to 98 percent, with a mean of 76 percent. Gene had fewest infected plants (24 percent), Lewjain was intermediate (76 percent), and Malcolm had the most (98 percent). Samples of Madsen had 37-98 percent infected plants and Stephens had 62-96 percent, illustrating large differences that may occur within varieties. Similar ranges occurred for percentages of tillers affected for each variety; 6 percent for Gene, 12-79 percent for Madsen, 36 percent for Lewjain, 39-81 percent for Stephens, 67 percent for Weston, and 90 percent for Malcolm. These results are comparable to provisional disease susceptibility groupings from rankings in wheat breeding nurseries in Oregon (Table 1). Gene and Madsen are considered tolerant, Lewjain intermediate, and Stephens and Malcolm susceptible. Weston was not evaluated in the breeding nurseries.

Dryland root rot reduced all plant and yield characteristics examined (Table 2).

Table 2. Relationship between dryland root rot severity, plant characteristics, yield and yield components for winter wheat plants sampled from 13 randomly selected fields in Oregon and Washington during 1994.

Plant characteristic	Disease severity rating†					
	D_0	D_1	D_2	D_3	D_4	lsd (0.05)
Tillers in class (%)	47	25	17	6	5	-
Kernels/head	21	20	20	16*	6*	3
Grain protein (%)‡	12.6	12.5	13.0	13.3	14.2	ns
Kernel weight (mg)	43	42	41	36*	33*	3
Grain weight/head (mg)	899	806	794	673*	399*	119
Tillers with heads (%)	96	82*	85*	80*	84*	8
Straw weight/tiller (g)	1.7	1.6	1.7	1.6	0.9*	0.3
Tiller height (cm)	73	72	71	68*	64*	2
Reduction in grain yield from disease (%)	0	10	12*	28*	30*	10

† Root rot severity classes were: D_0 (none), D_1 (browning up to the first node), D_2 (second node), D_3 (third node), and D_4 (4th node or above).

‡ Two samples of Weston winter wheat were excluded from this analysis because the objective of producing high-protein grain (>13%) for this variety differed from the objective of producting low protein (<10%) in the soft white winter wheat varieties included in this analysis.

* Designates values, within a row, that differ significantly (p<0.05) from the D_0 value.

Increasing disease severity ratings were associated with decreasing numbers of kernels/head, kernel weight, grain weight/head, percentage tillers with heads, straw weight/tiller, and head height.

Grain protein content ranged from 8.2 to 16.7 percent in the 13 fields. Six fields had protein contents of 12 percent or lower, and four exceeded 14 percent. Protein content was not associated with variety or county. Stephens was produced in fields with the highest and lowest protein content, and samples of Weston (a hard red, bread wheat) had protein contents with the second- and fourth-highest rankings. There was a tendency for protein in soft white varieties to increase with severity of disease (Table 2), but this relationship was not statistically significant for the 11 fields analyzed. Excessively high protein contents in these samples apparently masked a more pronounced effect of root rot on protein than was anticipated by the authors.

The five fields with lowest protein, except the field of Gene that was not affected by dryland root rot, were evaluated as a sub-group to determine grain yield and quality responses to dryland root rot in situations where soil fertility was apparently not high enough to promote excessive grain protein contents for soft white winter wheat. This sub-group included the varieties Stephens (3 samples), Malcolm (1), and Lewjain (1) collected from Sherman (1 field), Gilliam (3), and Benton (1) Counties. Compared to the 13-field analysis (Table 2),

Table 3. Relationship between dryland root rot severity, plant characteristics, yield and yield components for soft white winter wheat plants from a 5-field, lower-protein (<12%), sub-group of 13 randomly selected fields† in Oregon and Washington during 1994.

Plant characteristic	Disease severity rating ‡					
	D_0	D_1	D_2	D_3	D_4	lsd (0.05)
Tillers in class (%)	38	26	23	6	7	-
Kernels/head	20	18	19	17	9*	5
Grain protein (%)	10.8	10.5	11.0	11.6*	12.9*	0.7
Kernel weight (mg)	45	44	43	37*	24*	7
Grain weight/head (mg)	871	784	795	605*	288*	194
Tillers with heads (%)	98	88*	89*	88*	93	8
Straw weight/tiller (g)	1.8	1.7	1.7	1.7	1.2*	0.4
Tiller height (cm)	72	72	71	55*	40*	15
Reduction in grain yield from disease (%)	0	14	14*	30*	39*	19

† Gene winter wheat had low protein (9.9%) but was excluded from this analysis because the variety was not affected by dryland root rot.

‡ Root rot severity classes were: D_0 (none), D_1 (browning up to the first node), D_2 (second node), D_3 (third node), and D_4 (4th node or above).

* Designates values, within a row, that differ significantly (p<0.05) from the D_0 value.

Table 4. Estimates of percentage yield loss (%YL) from dryland root rot in 13 randomly selected winter wheat fields in four Oregon and Washington counties during 1994, based on percentages of tillers with culm browning symptoms to the fourth node or higher (D_4).

Type and number of fields evaluated	Yield loss equation	p	r^2	df
Randomly selected (13)	$\%YL = 3.5 + 1.1 (\%D_4)$	<0.001	0.66	25
Stephens only (5)	$\%YL = 0.9 + 1.1 (\%D_4)$	<0.001	0.82	9
Low-protein only (5)	$\%YL = 4.1 + 1.1 (\%D_4)$	<0.001	0.89	9

Table 5. Relationships between dryland root rot and yield loss in two sub-groups (four with "light" and four with "heavy" disease damage[†]) of 13 randomly selected Oregon and Washington winter wheat fields during 1994.

Disease severity group	Plants with root rot (%)	Headed tillers per foot of row	Headed tillers (%) in disease severity class:					Yield loss (%)	Grain protein (%)
			D_0	D_1	D_2	D_3	D_4		
Light	63	47	67	29	19	3	1	2.5	13.1
Heavy	87	41	25	15	14	12	15	17.7	13.5
lsd (0.05)	ns	ns	15	6	ns	6	7	9.9	ns

[†] Lightly affected fields include two each of Stephens and Madsen, and heavily affected fields included three of Stephens and one of Madsen. Root rot severity classes were: D_0 (none), D_1 (browning up to the first node), D_2 (second node), D_3 (third node), and D_4 (4th node or above).

.

the 5-field lower-protein sub-group (Table 3) exhibited more pronounced effects of root rot on grain protein, kernel weight, grain weight/head, tiller height, and yield loss. Protein content was significantly increased with disease severity.

When all tillers were considered, dryland root rot in the 13 fields reduced yields by 0 to 35 percent (average of 9 percent). Grain yield was correlated with the percentage of tillers in disease severity class D_4. Yield declined by 1 percent for each 1 percent of tillers in D_4 (Table 4). Similar relationships were found for calculations based on the five fields planted to Stephens, and the five lower-protein fields.

Yield loss relationships were also evaluated by comparing two groups of four fields selected for either high or low root rot severity, from among the 13 fields sampled. Yield losses for plants in four "lightly" and four "heavily" affected fields averaged 3 percent and 18 percent, respectively (Table 5). Numbers of plants with root rot and numbers of headed tillers/foot of row were similar in the light and heavily affected fields. Compared to heavily affected fields, lightly affected fields had a higher proportion of tillers in disease severity classes D_0 and D_1, and a lower proportion of tillers in classes D_3 and D_4. Protein did not differ significantly among groups of fields when evaluated on the basis of entire bundles (Table 5) or sub-samples for disease severity classes D_0 (healthy) through D_3 (moderately severe). Grain from D_4 tillers had higher protein in the heavily affected than lightly affected fields (protein contents were 15.7 and 12.5 percent, respectively; lsd=2.0).

These data indicate that yield losses from dryland root rot are important in semi-arid regions of eastern Oregon and Washington, where 185 million bushels of winter wheat were produced on 3.2 million acres in 1992, for a farm gate value exceeding $700 million. Average yield in these counties during 1992 was 42 bushel/acre, and the average market price for grain was $3.85/bushel. A 9 percent yield loss for the 13-field sample represents a direct economic loss of $15.40/acre. The 18 percent loss in four heavily affected fields represented a negative impact of $30.80/acre. The 13 fields were selected at random, before symptoms of dryland root rot were evident. If the varieties and climates of these fields and counties represent 20 percent of the non-irrigated acreage in eastern Oregon and Washington, estimates of direct economic damage from dryland root rot in the region would be 3.6 million bushels, or $14 million. Further economic loss would occur if test weight decreased, or protein increased, to the extent of reducing the market grade for grain produced.

Dryland root rot occurs with variable intensity across most fields, causing difficulty in assigning a "field average" without intensive sampling protocols in the field followed by labor-intensive assessments performed tiller by tiller. Research reported here is being repeated and expanded during 1995 to determine if yield loss assessments can be based reliably on percentages of whiteheads rather than number of tillers in D_4. Whiteheads can be enumerated much more easily than disease classifications on culms.

ACKNOWLEDGMENTS

We appreciate the assistance of Extension Service Agents (Walt Gary, Phil Nesse, Sandy Macnab, Brian Tuck, and Greg Van Doren), wheat producers in eastern Oregon and Washington, and technical assistance from Darrick Cope and EmmaLee Hemphill. We also appreciate financial assistance from the Oregon Wheat Commission and USDA-CSRS-Pacific Northwest STEEP II Research Program. Disease severity rankings for varieties were from data collected in trials coordinated by Drs. Pamela Zwer, Russell Karow, and Warren Kronstad. The study was performed as a component of Oregon Agricultural Experiment Station Project 268.

READING LIST

Cook, R.J. 1980. Fusarium foot rot of wheat and its control in the Pacific Northwest. Plant Dis. 64:1061-1066.

Cook, R.J. 1981. Fusarium diseases of wheat and other small grains in North America. p. 39-52 *in*: *Fusarium*: Diseases, Biology, and Taxonomy. P.E. Nelson, T.A. Toussoun, and R.J. Cook, eds. Pennsylvania State Univ. Press, University Park, PA.

Cook, R.J., and R.J.Veseth. 1991. Wheat Health Management. Amer. Phytopathol. Soc., St. Paul, MN. 152 p.

Smiley, R.W., and L.-M. Patterson. 1995. Pathogens associated with dryland root rot in eastern Oregon and Washington. Oregon Agric. Expt. Sta. Spec. Report xxx: (this issue).

Teng, P.S., and W.W. Shane. 1984. Crop losses due to plant pathogens. CRC Rev. Plant Sci. 2:21-47.

Wiese, M.V. 1987. Compendium of Wheat Diseases, 2nd ed., Amer. Phytopathol. Soc., St. Paul, MN. 112 p.